satisfied. According to “IEEE TRANSACTIONS ON ELECTRON DEVICE,” Vol. 52, No. 10, OCTOBER, 2005, p. 2124, favorable ohmic contact can be formed because polarization possessed by the contact layer and polarization possessed by the barrier layer cancel each other at an interface between the contact layer and the barrier layer and consequently depletion at the interface between the contact layer and the barrier layer can be prevented, by setting Y so as to generate polarization greater than the AlGaN layer when the relation $Z=4.66\times Y$ is satisfied.

[0014] A nitride semiconductor device having a configuration obtained by stacking a buffer layer formed of a GaN film and a barrier layer formed of an AlGaN film is known as a fourth reference art (see “IEEE TRANSACTIONS ON ELECTRONICS,” Vol. E82-C, No. 11, NOVEMBER, 1999, p. 1895). In the fourth reference art, the barrier layer is smaller in lattice constant than the buffer layer, and consequently strain is caused in the barrier layer. In the nitride semiconductor, two-dimensional electron gas is formed at the interface between the buffer layer and the barrier layer by a piezo effect caused by the strain in the barrier layer. Therefore, the nitride semiconductor device according to the fourth reference art can be made to operate as a field effect transistor by forming a source electrode, a drain electrode and a gate electrode on the barrier layer.

[0015] A nitride semiconductor device having a configuration obtained by stacking a buffer layer formed of a GaN film, a first barrier layer formed of an AlGaN film, a channel layer formed of a GaN film and a second barrier layer formed of an AlGaN film is known as a fifth reference art (see JP-A 2001-196575 (KOKAI)). In the fifth reference art, residual carriers in the buffer layer are prevented from influencing the channel layer by the first barrier layer. By forming a source electrode, a drain electrode and a gate electrode on the second barrier layer, therefore, the nitride semiconductor device according to the fifth reference art can be made to operate as a field effect transistor with the influence of the residual carriers in the buffer layer excluded as compared with the nitride semiconductor device according to the fourth reference art.

[0016] If in the nitride semiconductor device according to the fifth reference art a buffer layer formed of a GaN film, a first barrier layer formed of an InAlGaN film, a channel layer formed of a GaN film and a second barrier layer formed of an AlGaN film are stacked and the In composition ratio in the first barrier layer is in the range of 0.3 to 0.7, then the density of electrons stored in the channel layer can be increased by the spontaneous polarization and piezo polarization caused in the first barrier layer.

[0017] In the case of the nitride semiconductor device in which the gate electrode and the source electrode/drain electrode are formed on barrier layers having the same thickness as in the first reference art, a two-dimensional electron system having uniform carrier densities is formed at the interface between the carrier transit layer and the barrier layer when the film thickness of the barrier layer is equal to or greater than the critical film thickness T_C indicated by the equation (2). Therefore, a two-dimensional electron system is formed at the interface between the carrier transit layer and the barrier layer, located between the source electrode and the gate electrode and between the drain electrode and the gate electrode as well. As a result, the on-resistance becomes low. Since a two-dimensional electron system having a finite carrier density exists under the gate electrode as well, the nitride semiconductor device becomes normally-on type.

[0018] On the other hand, when the film thickness of the barrier layer is equal to or less than the critical film thickness T_C indicated by the equation (2), the carrier density of the two-dimensional electron system under the gate electrode becomes zero, resulting in a normally-off type nitride semiconductor device. However, the carrier density of the two-dimensional electron gas becomes zero at the interface between the carrier transit layer and the barrier layer, located between the gate electrode and the drain electrode and between the gate electrode and the source electrode as well besides under the gate electrode. As a result, the resistance between the drain electrode and the source electrode becomes large and the on-resistance also becomes high. In other words, as for the nitride semiconductor device according to the first reference art, it is difficult to fabricate a normally-off type nitride semiconductor device having low on-resistance with a high yield.

[0019] On the other hand, in the case of the nitride semiconductor device in which the recess structure is formed by removing a part of the barrier layer and the film thickness of the barrier layer under the gate electrode is decreased as in the second reference art, the two-dimensional electron system is formed at the interface between the carrier transit layer and the barrier layer, located between the source electrode and the gate electrode and between the drain electrode and the gate electrode and consequently the on-resistance becomes low, when the film thickness of the barrier layer between the source electrode and the gate electrode and between the drain electrode and the gate electrode is equal to or greater than the critical film thickness T_C. If the film thickness of the barrier layer under the gate electrode is equal to or less than the critical film thickness T_C, the carrier density of the two-dimensional electron system under the gate electrode becomes zero. As a result, the nitride semiconductor device according to the second reference art can be implemented as a normally-off type nitride semiconductor device.

[0020] Considering the energy difference in the conduction band between the carrier transit layer and the barrier layer required to implement the two-dimensional electron system, it is desirable that the Al composition ratio Y of the barrier layer is at least 0.2. At this time, it is necessary that the film thickness of the barrier layer is equal to or less than approximately 60 Å according to the equation (2) in order to make the carrier density under the gate electrode equal to zero. For implementing the normally-off type semiconductor device by using the recess structure, processing of forming the carrier transit layer, the barrier layer and the contact layer one after another by using an epitaxial crystal growth equipment and then removing a part of the barrier layer while exercising control so as to have a film thickness of 60 Å or less with high precision. Because of the problem of the processing precision, however, there is a problem that it is difficult to fabricate the normally-off type semiconductor device with a high yield.

[0021] It is known that use of dry etching such as the RIE method on the nitride causes introduction of etching damages due to the nitrogen vacancy into the semiconductor